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Glossary

New Commercial Reactor Designs

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New Reactor Designs

Reactor Design	Vendor	Approximate Capacity (MWe)	Reactor Type	Certification Status	Target Certification
AP600	Westinghouse	650	PWR	Certified	Certified
AP1000*	Westinghouse	1117	PWR	Certified	Certified
ABWR*	GE et al	1371	BWR	Certified	Certified
System 80+	Westinghouse	1300	PWR	Certified	Certified
ESBWR*	GE	1550	BWR	Undergoing certification	2007
EPR*	AREVA NP	1600	PWR	Pre-certification	2009
PBMR	Westinghouse, Eskom	180	HTGR	Pre-certification	Not Available
IRIS	Westinghouse et al	360	PWR	Pre-certification	2010
US APWR	Mitsubishi	1600	PWR	Undergoing certification	2011
ACR Series	AECL	700-1200	Modified PHWR	Pre-certification	Not Available
GT-MHR	General Atomics	325	HTGR	Research prototype planned	Not Available
4S*	Toshiba	10-50	Sodium-cooled	Potential construction	Not Available

Note: Data are approximate targets which may change. Reactor types are defined below. Designs marked with an asterisk (*) are also supported by electricity generating firms or organizations publicly investigating possible construction in the U.S. AECL is Atomic Energy of Canada Limited.

This document supersedes an earlier publication entitled "New Reactor Designs". Criteria for inclusion on the preceding table are:
Design certification issued by the Nuclear Regulatory Commission (AP600, AP1000, APWR, System 80+)

1. Submission to the Nuclear Regulatory Commission (NRC) of an application for design certification (ESBWR, USAPR)
2. Recent pre-design certification activities with the NRC or public announcement of such intentions (EPR, PBMR, IRIS, ACR series reactors)
3. A research reactor design that has been discussed with the NRC that might lead to a commercial prototype (GT-MHR)
4. Selected additional designs that appear to be intended for eventual construction in the US. (4S)

Excluded are:

1. Reactors that do not appear to be intended for the US market.
2. Reactors that are components of US government programs that have not yet been identified for targeted design certification. This excluded list includes many designs

associated with Generation IV (Gen IV) reactor designs (included in the previous edition of “New Reactor Designs”), the Next Generation Nuclear Power (NGNP) program, and the Global Nuclear Energy Partnership (GNEP). Such reactor designs will be included after the designs are publicly identified for design certification. Gen IV reactors are summarized on http://nuclear.inl.gov/gen4/index.shtml.

Reactor Types

1. **Pressurized Water Reactors (PWR):** PWRs use nuclear-fission to heat water under pressure within the reactor. This water is then circulated through a heat exchanger (called a "steam generator") where steam is produced to drive an electric generator. The water used as a coolant in the reactor and the water used to provide steam to the electric turbines exists in separate closed loops that involve no substantial discharges to the environment. Of the 104 fully licensed reactors in the United States, 69 are PWRs. Westinghouse, Babcock and Wilcox, and Combustion Engineering designed the designed the nuclear steam supply systems (NSSS) for these reactors. After these reactors were built, Westinghouse and Combustion Engineering nuclear assets were combined. The French-German owned firm Areva NP has acquired many of Babcock and Wilcox's nuclear technology rights, though portions of the original Babcock and Wilcox firm still exist and possess some nuclear technology rights as well. Other major makers of PWR reactors, including Areva, Mitsubishi, and Russia’s Atomstroyexport, have not yet sold their reactors in the U.S. www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/pwr.html
2. **Boiling Water Reactors (BWR):** The remaining 35 operable reactors in the United States are BWRs. BWRs allow fission-based heat from the reactor core to boil the reactor’s coolant water into the steam that is used to generate electricity. General Electric built all boiling water reactors now operational in the United States. Areva NP and Westinghouse BNFL have each designed BWRs.www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/bwr.html
3. **Pressurized Heavy Water Reactors (PHWR):** PHWRs have been promoted primarily in Canada and India, with additional commercial reactors operating in South Korea, China, Romania, Pakistan, and Argentina. Canadian-designed PHWRs are often called "CANDU" reactors. Siemens, ABB (now part of Westinghouse), and Indian firms have also built commercial PHWR reactors. Heavy water reactors now in commercial operation use heavy water as moderators and coolants. The Canadian firm, Atomic Energy of Canada Limited (AECL), has also recently proposed a modified PHWR (the ACR series) which would only use heavy water as a moderator. Light water would cool these reactors. No successful effort has been made to license commercial PHWRs in the United States. PHWRs have been popular in several countries because they use less expensive natural (not enriched) uranium fuels and can be built and operated at competitive costs. The continuous refueling process used in PHWRs has raised some proliferation concerns because it is difficult for international inspectors to monitor. Additionally, the relatively high Pu-239 content of PHWR spent fuel has also raised proliferation concerns. The importance of these claims is challenged by their manufacturers. PHWRs, like most reactors, can use fuels other than uranium and the ACR series of reactors is intended to use slightly enriched fuels. Particular interest has been shown in India in thorium-based fuel cycles. http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/china/candu.html
4. **High Temperature Gas-cooled Reactors (HTGR):** HTGRs are distinguished from other gas-cooled reactors by the higher temperatures attained within the reactor. Such higher temperatures might permit the reactor to be used as an industrial heat source in addition to generating electricity. Among the future uses for which HTGRs are being considered is the commercial generation of hydrogen from water. In some cases, HTGR turbines run directly by the gas that is used as a coolant. In other cases, steam or alternative hot gases such as nitrogen are produced in a heat exchanger to run the power generators. Recent proposals have favored helium as the gas used as

an HTGR coolant. The most famous U.S. HTGR example was the Fort Saint Vrain reactor that operated between 1974 and 1989. Other HTGRs have operated elsewhere, notably in Germany. Small research HTGR prototypes presently exist in Japan and China. Commercial HTGR designs are now promoted in China, South Africa, the United States, the Netherlands, and France though none of these is yet commercially marketed. The proposed Next Generation Nuclear Plant (NGNP) in the U.S. will most likely be a helium-based HTGR, if it is funded to completion. http://www.nuc.berkeley.edu/designs/mhtgr/mhtgr.GIF

5. **Sodium-cooled reactors reactors:** Sodium-cooled reactors are included on this list primarily because of proposals to build a Toshiba 4S reactor in Alaska. Sodium-cooled reactors use the molten (liquid) metal sodium as a coolant to transfer reactor generated heat to an electricity generation unit. Sodium-cooled reactors are often associated with "fast breeder reactors (FBRs)" though this is technically not the case in the 4S design.

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AP600

(Westinghouse)
Synonyms: Advance Passive 600
Approximate Capacity (electric): 600 MWe
Reactor Type: Pressurized Water Reactor
NRC Design Certification Status: Certified December 1999
Supporting Generating Companies (potential site): None
The AP600 is a 600 MW PWR certified by the NRC. While based on previous PWR designs, the AP600 has innovative passive safety features that permit a greatly simplified reactor design. Simplification has reduced plant components and should reduce construction costs. The AP600 has been bid overseas but has never been built. Westinghouse has deemphasized the AP600 in favor of the larger, though potentially even less expensive (on a cost per kilowatt or capacity basis) AP1000 design.
Further Information: http://www.ap600.westinghousenuclear.com/ http://www.nei.org/index.asp?catnum=3&catid=704

AP1000

(Westinghouse)
Synonyms: Advanced Passive 1000
Approximate Capacity (electric): 1117-1154 MWe
Reactor Type: Pressurized Water Reactor
NRC Design Certification Status: Certified after December 2005, though amendments have since been proposed.
Supporting Generating Companies (potential site): Duke Power (Cherokee County), Progress Energy (Harris), Southern Company (Vogtle), NuStart Energy-Tennessee Valley Authority (Bellefonte)
The AP1000 design is favored for construction at five to six potential sites (ten to twelve reactors) in the United States. The AP1000 is an enlargement of the AP600, designed to almost double the reactor's target electricity output without proportionately increasing the total cost of building the reactor. Westinghouse anticipates that operating costs should be below the average of reactors now operating in the United States. While Westinghouse owns rights to several other designs, the AP1000 is the principal product that the company now promotes in the United States for near term deployment. The

AP1000 includes innovative, passive safety features and a much simplified design intended to reduce the reactor's material and construction costs while improving operational safety. During 2007 or 2008 it is anticipated that the AP1000 will be the subject of combined license (COL) applications to build and operate new reactors in the United States. In early 2005 Westinghouse submitted a bid to build a version of the AP1000 to build as many as four AP1000s at two sites in China.
Further Information: http://www.nrc.gov/reactors/new-licensing/design-cert/ap1000.html http://www.ap1000.westinghousenuclear.com/ http://en.wikipedia.org/wiki/AP1000 http://www.nei.org/doc.asp?docid=770

ABWR

(General Electric and others)
Synonyms: Advanced Boiling Water Reactor
Approximate Capacity (electric): 1371-1465 MWe
Reactor Type: Boiling Water Reactor
NRC Design Certification Status: Certified May 1997. Design amendments are possible but have not been publicly announced.
Supporting Generating Companies (potential site): NRG Energy (South Texas Project); Amarillo Power
Four ABWRs operate in Japan and more are planned there. Two additional ABWRs are under construction in Taiwan and two units are being considered for the South Texas Project site in the United States. While the ABWR design is usually associated in the United States with General Electric, variations on the design have also been built by Toshiba and Hitachi. Hitachi also hopes to associate with General Electric for building additional ABWRs at the South Texas Project. The Tennessee Valley Authority (TVA) published a study of the costs of building an ABWR reactor in the United States in September 2005 (below). Vendors now claim costs for building the ABWR that are low enough that they have attracted some customer interest.
Further Information:
http://www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors/abwr.htm http://en.wikipedia.org/wiki/ABWR http://www.nei.org/doc.asp?catnum=&catid=&docid=110&format=print http://np2010.ne.doe.gov/reports/Main%20Report%20All5.pdf http://www.nuc.berkeley.edu/designs/abwr/abwr.html

System 80+

(Westinghouse)
Synonyms: None
Approximate Capacity (electric): 1300 MWe plus
Reactor Type: Pressurized Water Reactor
NRC Design Certification Status: Certified May 1997.
Supporting Generating Companies (potential site): A modified version of the design is being promoted for development in South Korea
The System 80+ reactor is a PWR designed by Combustion Engineering (CE) and by CE's successor owners ABB and Westinghouse. The NRC has certified the System 80+ for the U.S. market, but Westinghouse no longer actively promotes the design for domestic sale. The System 80+ provides a basis for the APR1400 design that has been developed in Korea for future deployment and possible export.
Further Information: http://www.nei.org/index.asp?catnum=3&catid=703 http://www.nuc.berkeley.edu/designs/sys80/sys80.html

ESBWR

(General Electric)
Synonyms: Sometimes called Economic Simplified Boiling Water Reactor or European Simplified Boiling Water Reactor though General Electric does not frequently use the name.
Reactor Type: Boiling Water Reactor
Approximate Capacity (electric): 1550 MWe plus
NRC Design Certification Status: Undergoing certification
Supporting Generating Companies (potential site): Entergy (Grand Gulf, River Bend), Dominion Energy (North Anna)
The ESBWR is a new simplified BWR design promoted by General Electric and some allied firms. The ESBWR constitutes an evolution and merging of several earlier designs including the ABWR. The ESBWR, which includes new passive safety features, is intended to cut construction and operating costs significantly from earlier ABWR designs. GE and others have invested heavily in the ESBWR though the design and two US utilities, Dominion and Entergy have expressed an interest in possibly building the design at three sites. These utilities have stated that they might apply for a combined license (COL) to build and operate new ESBWR reactors during 2007 or 2008. The two utilities have also applied for Early Site Permits (ESPs) for the designs which the anticipate receiving during 2007. The ESBWR is presently undergoing design certification with the NRC.
Further Information: http://www.nrc.gov/reactors/new-licensing/design-cert/esbwr.html http://www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors/esbwr.htm http://en.wikipedia.org/wiki/ESBWR http://www.nei.org/index.asp?catnum=4&catid=907 www.ans.org/pubs/magazines/nn/docs/2006-1-3.pdf

EPR

(Areva NP)
Synonyms: Evolutionary Pressurized Water Reactor, the name European Pressurized Water Reactor does not apply to the US design
Approximate Capacity (electric): 1600 MWe
Reactor Type: Pressurized Water Reactor
NRC Design Certification Status: Pre-application review
Supporting Generating Companies (potential site): UniStar Nuclear-Constellation-Areva (Calvert Cliffs, Nine Mile Point)
Areva NP announced in early 2005 that it would market its EPR design in the United States and has recently begun pre-certification activities. The U.S.-market version is called the Evolutionary Pressurized Water Reactor. The EPR is a conventional, though advanced, PWR in which components have been simplified and considerable emphasis is placed on reactor safety. The design is now being built in Finland with a target commercialization during 2010. The French government has also authorized building an EPR at Flamanville 3 in France. Additional EPRs might replace additional commercial reactors now operating in France starting in the late 2010s and EPRs have been bid, in China and elsewhere. The proposed size for the EPR has varied over time, but is most frequently placed around 1600 MWe. Earlier designs were as large as 1750 MWe. The EPR is promoted in the United States by UniStar Nuclear, a joint venture of Constellation Energy and AREVA NP. UniStar is presently looking at the possibility of building EPRs at Constellation-owned sites at Nine Mile Point and Calvert Cliffs and has had discussions with other firms. Areva NP anticipates submitting a design certification application to the Nuclear Regulatory Commission during late 2007.
Further Information: http://www.nrc.gov/reactors/new-licensing/design-cert/epr.html http://en.wikipedia.org/wiki/European_Pressurized_Reactor http://unistarnuclear.com/

PBMR

(Westinghouse, PBMR Ltd.)
Synonyms: Pebble Bed Modular Reactor
Approximate Capacity (electric): 165 MWe
Reactor Type: High temperature gas-cooled reactor (HTGR)
NRC Design Certification Status: Pre-application review
Supporting Generating Companies (potential site): The design has no U.S. generating company sponsor. The PBMR is supported by the South African utility Eskom for development in South Africa
The PBMR uses helium as a coolant and is part of the HTGR family of reactors. PBMR development is thus a product of a lengthy history of research, notably in Germany and the United States. More recently the design has been promoted and revised by PBMR Ltd., an affiliate of the South African utility Eskom. Westinghouse is a minority investor in PBMR Ltd. and has taken a leading role in U.S. design certification. The PBMR design is presently in a "pre-certification" status with the NRC. Prototype variations on the PBMR design now operate in China and Japan. Eskom has also received administrative approval to build a prototype PBMR in South Africa. If the prototype is successful, Eskom has stated it intends to build several follow on units. There is no U.S. generating company sponsor of the design. At around 165 MWe the PBMR would be one of the smaller reactors now proposed for the commercial market. This is considered a marketing advantage by some because small reactors require lower initial capital investments than larger new units. Several PBMRs could be built at a single site as local power demand requires. The NRC also does not claim the same familiarity with the PBMR design that it has with light water reactors (PWR and BWR). Fuels used in the PBMR would be more highly enriched than the uranium is now used in light water reactor designs. China and South Africa have also discussed cooperation in PBMR efforts.
Further Information: http://www.nrc.gov/reactors/new-licensing/design-cert/pbmr.html
http://www.pbmr.com/ http://en.wikipedia.org/wiki/Pebble_bed_modular_reactor
http://www.nei.org/index.asp?catnum=3&catid=707

IRIS

(Westinghouse-led consortium)
Synonyms: International Reactor Innovative and Secure
Approximate Capacity (electric): 100-300 MWe
Reactor Type: Pressurized Water Reactor (advanced design)
NRC Design Certification Status (potential site): Pre-application review
Supporting Generating Companies: None, though international generating companies are part of the international consortium developing the design.
Westinghouse has promoted the IRIS reactor design as a significant simplification and innovation in PWR technology. While the IRIS is a PWR, several components, notably steam generators, are internal to the reactor vessel. The reactor design is smaller than most operating PWRs and is asserted to be much simplified. Fuel for the IRIS would be more enriched (5-9% U-235 compared to 3-5%) than is presently used in U.S. PWR. This might allow for longer periods between reactor refueling. The IRIS reactor includes features intended to avoid loss of coolant accidents. Pre-certification is proceeding though IRIS might show its potential during the next decade (2010s). Certification activities as now scheduled could precede commercial availability. IRIS sponsors have a targeted 2010 certification completion date with commercial deployment to follow.
Further Information: http://hulk.cesnef.polimi.it/ http://www.nei.org/index.asp?catnum=3&catid=712

US-APWR

(Mitsubishi Heavy Industries)
Synonyms: International Advanced Pressurized Water Reactor, the name Advanced Pressurized Water Reactor (APWR) usually refers to the design in Japan
Approximate Capacity (electric): 1700 MWe in the United States
Reactor Type: Pressurized Water Reactor
NRC Design Certification Status: Pre-application review. Application targeted for March 2008.
Supporting Generating Companies (potential site): Support exists for the related APWR design among Japanese generating companies.
The US-APWR is a U.S.-marketed variation on APWR design sold in Japan by Mitsubishi Heavy Industries. The 1538 MW APWR has been selected by Japan Atomic Power Company for two units to be located at Tsuruga in Japan with the first unit slated for completion in 2014. Other Japanese generating companies are also interested in the APWR design. The 1700 MW US-APWR was only recently (June 2006) announced for the U.S. market and is not presently being certified in any other international markets. The US-APWR has not yet received publicized support from any U.S. generating company. Pre-application design certification activities before the U.S. Nuclear Regulatory Commission began during July 2006. Mitsubishi targets a design certification application for March 2008 and hopes complete the process during 2011. Mitsubishi also wants to have the reactor available for construction in the U.S. as early as 2011. Mitsubishi is also investigating certifying a second, smaller reactor design at a capacity of 1200 MW.
Further Information: http://en.wikipedia.org/wiki/Advanced_Pressurized_Water_Reactor
http://www.mhi-ir.jp/english/new/sec1/200607031122.html

ACR Series

(Atomic Energy of Canada Limited)
Synonyms: Advanced CANDU Reactor, ACR700, ACR1000
Approximate Capacity (electric): 700-1200 MWe
Reactor Type: Modified Pressurized Heavy Water Reactor
NRC Design Certification Status: Pre-application review apparently on hold.
Supporting Generating Companies(potential site): None, though it is among the designs being considered for eventual development in Ontario, Canada.
AECL's ACR series of reactors is considered by its vendor to be an evolution from the internationally successful CANDU line of PHWRs. Original pre-application design certification procedures in the U.S. had been for the 700 MW ACR700 design. More recent discussions have focused on the 1200 MW ACR1000. CANDU reactors and their Indian derivatives have had more success than any family of commercial power reactors except the LWRs. One of the innovations in the ACR series of reactors, compared to earlier CANDU designs, is that heavy water is used only as a moderator in the reactor. Light water is used as the coolant. Earlier CANDU designs used heavy water both as a moderator and as a coolant. This change makes it debatable whether the ACR design series are true PHWRs, PWRs, or a hybrid between the two designs. Fueling procedures for the ACR follow the earlier CANDU designs in that it occurs while the reactors are in service rather than during refueling outages. AECL has aggressively marketed the ACR series offering low prices, short construction periods, and favorable financial terms. As is the case for most non-LWR reactors, U.S. generating companies, nuclear engineers, and regulators have only limited familiarity with the design. Interest in the ACR series by Dominion Resources in Virginia and by United Kingdom generating companies has not been sustained. AECL has subsequently delayed its efforts to certify the design in the United States. The ACR series has been mentioned as a possible contender for construction in Ontario, the earliest possible reactor construction there might be either earlier CANDU designs or non-Canadian designs.
Further Information: http://www.nrc.gov/reactors/new-licensing/design-cert/acr-700.html
http://www.aecl.ca/Reactors/ACR-1000.htm http://www.aecl.ca/AssetFactory.aspx?did=88

http://en.wikipedia.org/wiki/Advanced_CANDU_Reactor

GT-MHR

(General Atomics)
Synonyms: Gas Turbine Modular Helium Reactor, Freedom Reactor (Entergy trademark)
Approximate Capacity (electric): 285 MWe
Reactor Type: High temperature gas-cooled reactor (HTGR)
NRC Design Certification Status: Pre-application review.
Supporting Generating Companies: Entergy (development only)
The GT-MHR is an HTGR developed by the U.S. firm, General Atomic. The most advanced plans for GT-MHR development relate to building reactors in Russia to assist in the disposal of surplus plutonium supplies. Parallel plans for commercial power reactors would use uranium-based fuels enriched to as high as 19.9 percent U-235 content. This would keep the fuel a fraction below the 20 percent U-235 enrichment that defines highly-enriched uranium. The U.S. utility, Entergy, has participated in GT-MHR development and promotion and uses the name "Freedom Reactor" for the design. A proposed research version of the reactor has been proposed for the University of Texas Permian Basin and affiliated institutions for Andrews County, Texas. Because coolant temperatures arising from HTGRs are much higher than from light water reactors, the design is viewed as a potential source of commercial heat. Particular attention has been paid to the design's potential to produce of hydrogen from water. The GT-MHR is considered, among many other designs, as a potential contender for the US Department of Energy's Next Generation Nuclear Plant (NGNP) program.
Further Information: http://gt-mhr.ga.com/ http://en.wikipedia.org/wiki/GT-MHR
http://www.nei.org/doc.asp?catnum=3&catid=711

4S

(Toshiba)
Synonyms: Super Safe, Small, and Simple
Approximate Capacity (electric): 10 MWe, larger possible
Reactor Type: Sodium-cooled
NRC Design Certification Status: Manufacturer and sponsor are developing a pre-application approach.
Supporting Generating Companies (potential site): Town of Galena, Alaska
The 4S is a very small molten sodium-cooled reactor designed by Toshiba. The reactor presently being considered is 10 MWe though larger and smaller versions exist. The 4S is intended for use in remote locations and to operate without refueling during its 30-year life. The 4S has been compared with a nuclear “battery” because it does not require refueling. The lack of refueling would mean that the reactor’s fuel supply would be a capital cost rather than an operating cost. It has been suggested that the fuel might be relatively low cost, reprocessed spent fuels originating from more conventional power reactors. Other potential fuels are uranium or uranium-plutonium alloys. If uranium is the fuel in the United States, plans call for 19.9 percent fuel enrichment, just below the 20 percent definition of highly enriched uranium. The use of molten-sodium as a coolant is not new, having been used in many fast breeder reactors. Toward the end of 2004 the town of Galena, Alaska granted initial approval for Toshiba to investigate building a 4S reactor in that remote location. The design is also under consideration for other locations in Alaska. Most recent discussions target completion around 2013, though the schedule is not firm. Galena and Toshiba officials discussed their plans with the NRC in early February 2005 and plan additional filings over the coming years. The NRC indicated that it was not familiar with the 4S design and that design certification (at vendor expense) might be costly and prolonged. Design certification can be incorporated in the COL process thus it is unclear if a separate design certification will be pursued, if the project continues.

Further Information: http://en.wikipedia.org/wiki/Toshiba_4S http://www.atomicinsights.com/AI_03-20-05print.html
http://www.iser.uaa.alaska.edu/Publications/Galena_power_draftfinal_15Dec2004.pdf#search='Toshiba 4S'

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